Spring 2017

Experimental analysis of r134a, r22, and r404 for an edibon taab: Air conditioning lab unit

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Experimental Analysis of R134a, R22, and R404 for An Edibon TAAB: Air Conditioning Lab Unit

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Spring 2017 Senior Capstone Project

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April 21, 2017

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Abstract

This paper presents an experimental analysis of an Ebidon® TAAB™: Air Conditioning Lab unit running on R-134a being compared with R22 and R404 refrigerants, a $24,449 piece of equipment purchased by the JMU ISAT Department. In this paper we will compare the performance of the R-134a refrigerant under a range of working conditions and compare them to how the system would run on R22 or R404. The experimental tests use varying fan speeds and the R-134a data collected is compared to simulated data collected for R22 and R404. Analysis of the collected data and simulated data will be compared on the basis of COP and the systems effectiveness to add or remove heat from the air. From testing the system it is seen that R134a has the higher COP, R22 has the highest heat transfer, air heat transfer as fan speed increases and R134a has the highest, realistic heat transfer effectiveness under same refrigerant-side temperature and pressure testing conditions.

Acknowledgements

This research and testing was supported by the James Madison University Integrated Science and Technology Department and Dr. Tony Chen. The opportunity to take place in such a research project to further my education would never be possible without the faculty of the department. I am grateful to to Dr. Chen for sharing his expertise in this field and guiding me along this journey. I would like to thank Dr.Chen for both his personal and professional guidance through my project. He has taught me a great deal of what it is like to be involved with scientific research.

Table of Contents

List of Figures

Figures

Tables

Chapter 1: Introduction

The first "refrigeration cycle" was when Ben Franklin evaporated liquid in a vacuum and noticed a significant temperature drop [4]. Later James Harrison patented a machine that compressed gas to a liquid and evaporated which absorbed heat which lead to him creating ice. This process would eventually be used on commercial scale [4].

By the 1920's there was a lot of dangerous refrigerants so companies came together to create a safer refrigerant, Chlorofluorocarbon, which later became known as "CFCs [4]." It was not until the 1970s that scientists started to see that CFCs were not as safe as they once thought. CFCs would be released into the atmosphere and the chlorine would react with unstable ozone turning it into oxygen molecules [3]. Ozone is located in the stratosphere and protects the Earth from ultraviolet light from the sun [3]. Currently new machines can use older refrigerants because they can manage the safety hazards better than the older machinery [4]. Also, today most of the refrigerants used are either Hydrochlorofluorocarbons or Hydrofluorocarbons, HCFCs or HFCs respectively. They are better than CFCs, but still cause damage to the ozone so it is predicted they will be phased out by 2030 and replaced with Hydrofluoroolefin, HFOs [4]. HFOs have an even lower global warming potential than HCFCs and HFCs [4].

Multiple acts have been put into place to try and counter the emissions of gases that destroy the ozone and environment. In 1987 many countries signed the Montreal Protocol [5]. The Montreal Protocol was used to phase out CFCs [5]. Scientists noticed a large hole in the ozone above Antarctica which bought attention to the problems with current refrigerants. Since the Montreal Protocol has been put into place the ozone hole has slowly been recovering [5]. There were multiple plans covered in the protocol to phase out CFCs, then reviewed to phase out HCFCs, and to finally switch to HFCs. HFCs don't deplete the ozone layer but have a high global warming potential [5]. At meeting in 2015 in Dubai 197 countries agreed to phase out HFCs in the future as well [5]. Another action taken was the Kyoto Protocol. The Kyoto Protocol was put into place to try and reduce the amount of greenhouse gases released into the atmosphere [1]. There were two periods of targets, 2008-2012 and 2012-current [1]. Certain countries were required to meet their targeted goals during the first period and other the second period. Some countries like Canada have dropped out of the protocol after the first period [1]. The United States has signed the protocol but has still not ratified it [1]. Finally there was the Paris Agreement. The Paris Agreement was put into place to limit pollution and keep the overall temperature rises to less than 2°C from pre-industrial levels [6]. Other goals include increasing the ability to adapt new ways to lower greenhouse gas emissions that do not affect food production and making sure financial flows do not change with changes to lower greenhouse emission options [6].

The aim of this experiment is to compare and contrast different refrigerants by looking at their COPs, cooling capacities and effectiveness of adding or removing heat from a working fluid. The results of the R22 and R404 will be compared to R134a acting as a baseline for comparison.

Chapter 2: The Edibon TAAB: Air Conditioning Lab Unit

In this experiment tests are carried out on a 220V TAAB: Air Condition Lab Unit. The main components of the unit include: controlled variable speed fan, area for steam injection in front of the fan, two resistance heaters, evaporator, compressor, condenser, expansion valve high pressure switch, filter, flow meter, four numbered hygrometers that measure a total of four wet bulb and four dry bulb temperatures on the air side (located at the fan inlet, after the pre-heater, air cooling/dehumidification and after reheating,) and three numbered temperature sensors with attached pressure sensors on the refrigerant side (located at the outlet of the evaporator, outlet of the compressor, and outlet of the expansion valve.)

The lab unit is controlled by an electronic console as shown in figure 1 below. The electronic console has eight ports where the four hygrometers connect to show air temperature readings and three additional ports for the refrigerant temperature readings. These readings are changed using a numbered knob referring to the hygrometer and refrigerant sensor numbers. The console contains ON/OFF switches for the fan, condenser and overall power to the system.

Along with an ON/OFF switch for the fan there is a knob to change the speed of the fan. Finally there are two controllers on the console to change desired temperature of the two heating elements.

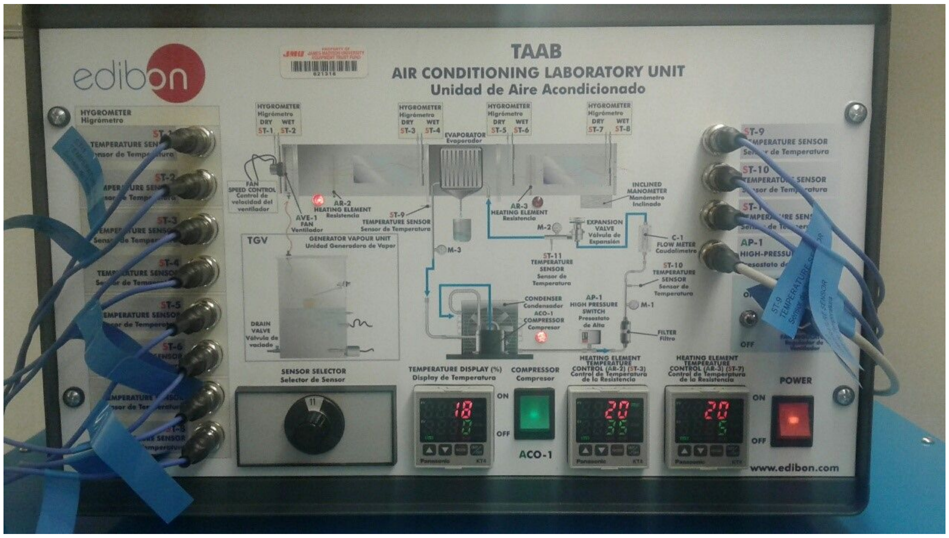

Figure 1: The electric control panel used to control the air conditioner's fan and heater settings.

Chapter 3: Testing Heat Transfer of Air

The thermodynamic properties of the air are measured using the four hydrometers that take dry and wet bulb temperatures. The heating elements are set to 35°C and 5°C and the fan is first set to 12 o'clock. An anemometer is placed at the end of the system to measured to velocity of the air. The diameter of the system opening is measured using a ruler. The air velocity is measured in m/s using an anemometer. Finally the pressure of the system is measured by looking at the pitot located under the system. The system runs until all the temperature readings remain constant. The temperature readings can be observed by using the numbered knob on the control console. This process is repeated two more times with the fan dial set at the 3 o'clock position and the 6 o'clock position.

Figure 2: The electronic control panel's fan speeds set to the 12 o'clock, 3 o'clock and 6 o'clock positions.

After the data is collected, Engineering Equation Solver (EES) files are created to find more thermodynamic properties of the air. With the pressure and temperature values of the air EES is used to to find properties like enthalpy and relative humidity which are required for later calculations.

The transfer of heat, in kW is found using equation (1)

$$\dot{Q}_{evap,air} = \rho A_{opening} V\left(h_{2,air} - h_{3,air}\right) \qquad (1)$$

Where Q is the heat transfer of the air, rho is the density of the air, V is the velocity, h_2 is condensor inlet enthalpy and h_3 is the condenser outlet enthalpy. The kW are then converted into Btu/hr. To double check the outcome the velocity of air is calculated using the Area of the duct, area of the opening and difference in pressure between the system and surroundings. The velocity is calculated using equation (2)

$$V_{calculated,opening} = \sqrt{\frac{2(\frac{1}{\rho})\Delta P}{\left(1 - \frac{A_{opening}^2}{A_{duct}^2}\right)}} \tag{2}$$

Where rho is the density, ΔP is the pressure difference between the system and surroundings, $A_{opening}$ is the area of the opening at the end of the system and A_{duct} is the area of the duct. The calculated velocity is then plugged into equation (1) to check our work.

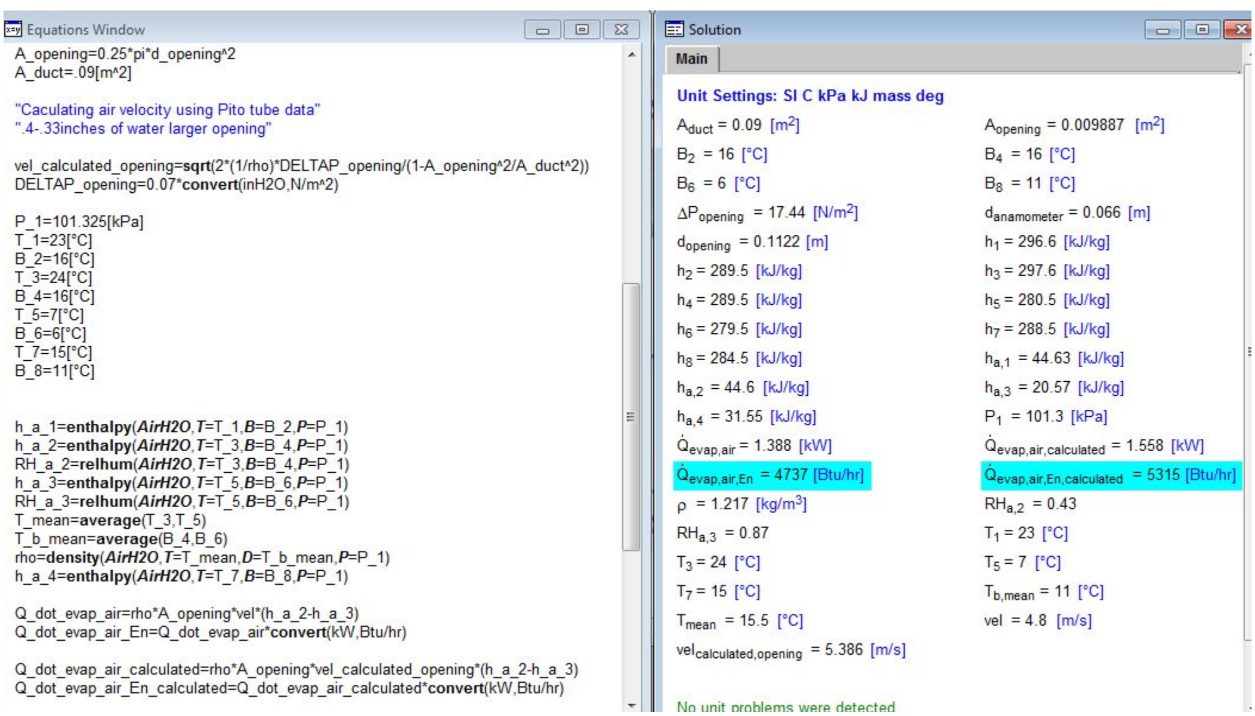

Figure 3: A screenshot of EES of the air side data collected with the fan set at 12 o'clock with the thermodynamic properties, measured and calculated air velocity and the heat transfer of the air from the measured and calculated velocity.

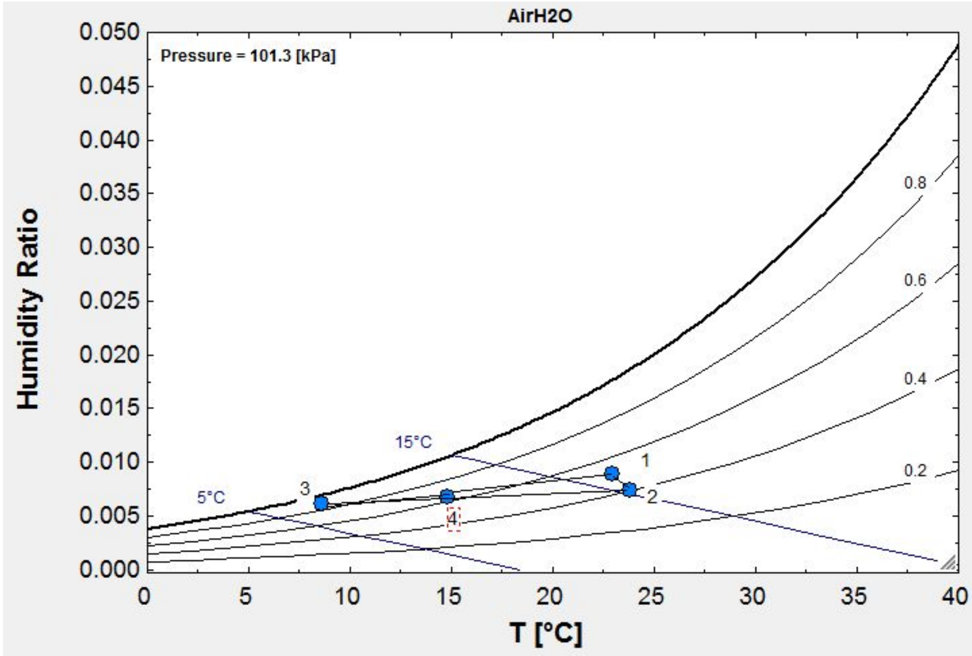

Figure 4: A screenshot of EES of the air side data at 12 o'clock plotted on a psychrometric chart.

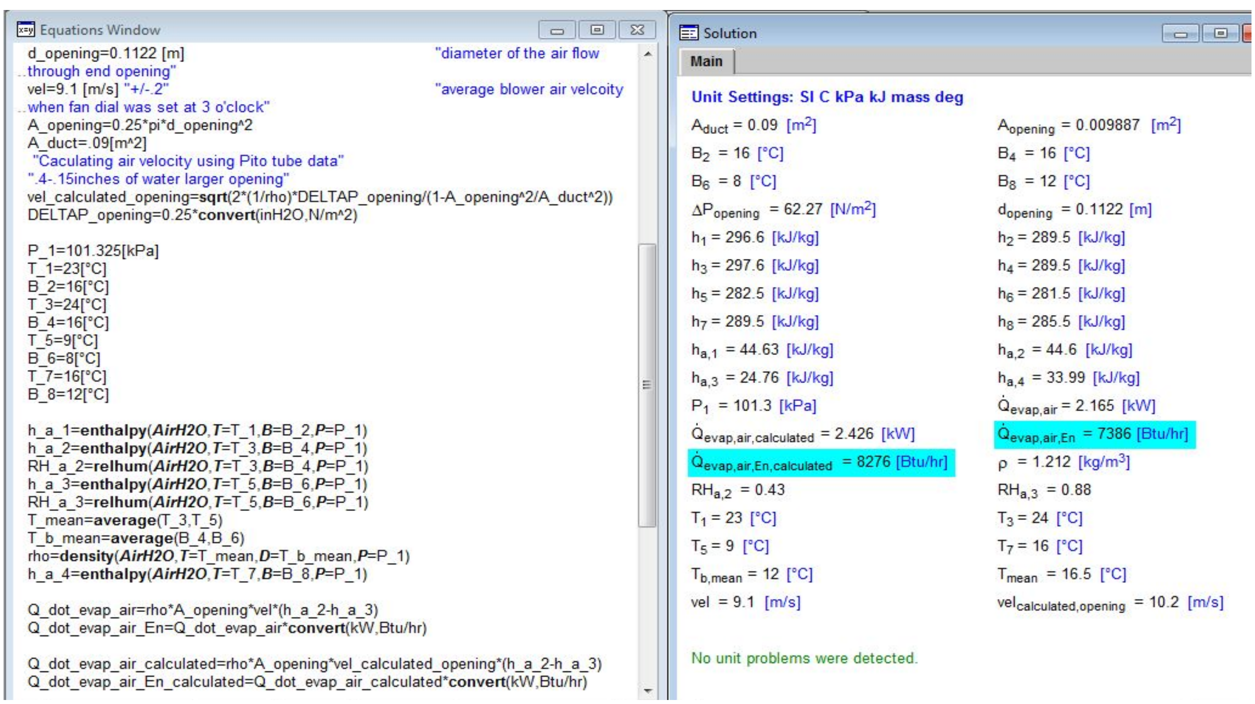

Figure 5: A screenshot of EES of the air side data collected with the fan set at 3 o'clock with the thermodynamic properties, measured and calculated air velocity and the heat transfer of the air from the measured and calculated velocity.

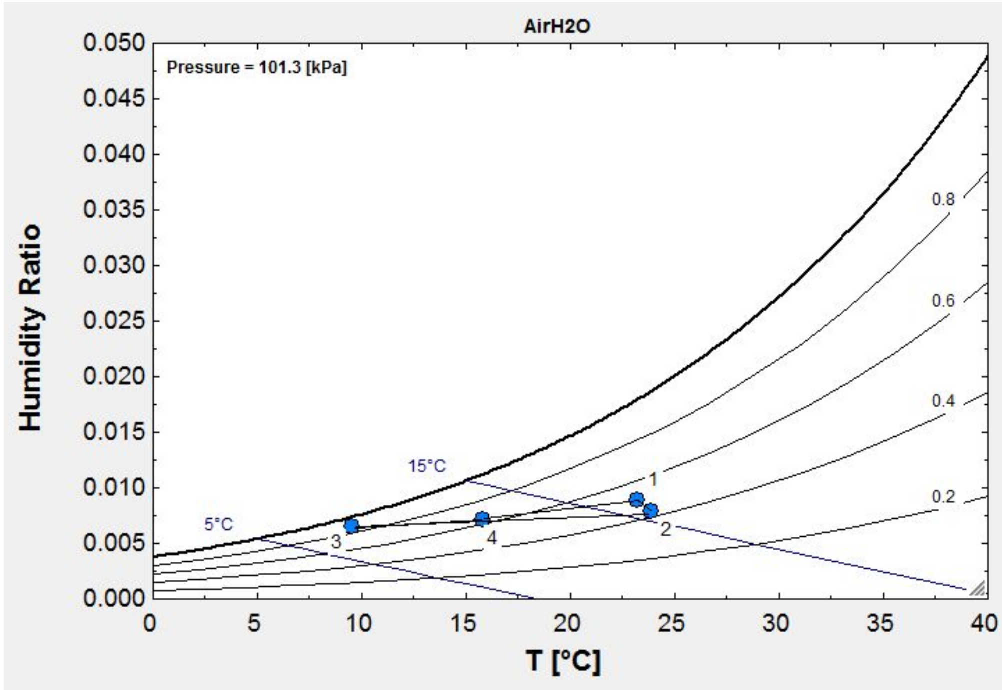

Figure 6: A screenshot of EES of the air side data at 3 o'clock plotted on a psychrometric chart.

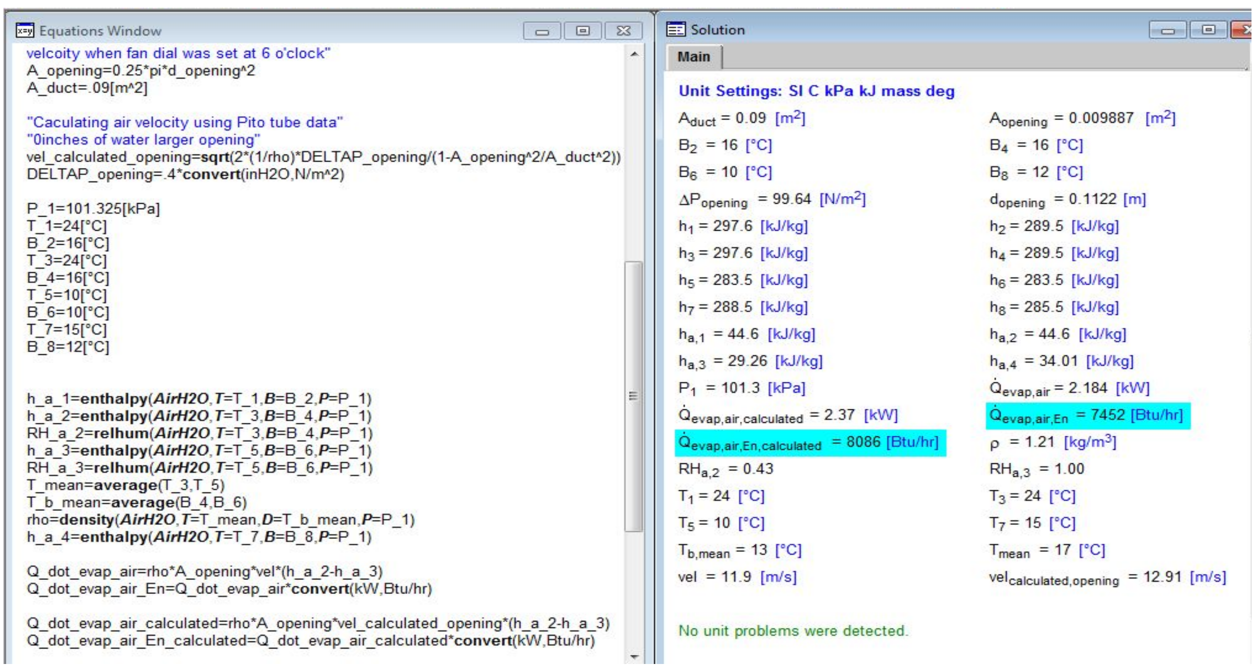

Figure 7: A screenshot of EES of the air side data collected with the fan set at 6 o'clock with the thermodynamic properties, measured and calculated air velocity and the heat transfer of the air from the measured and calculated velocity

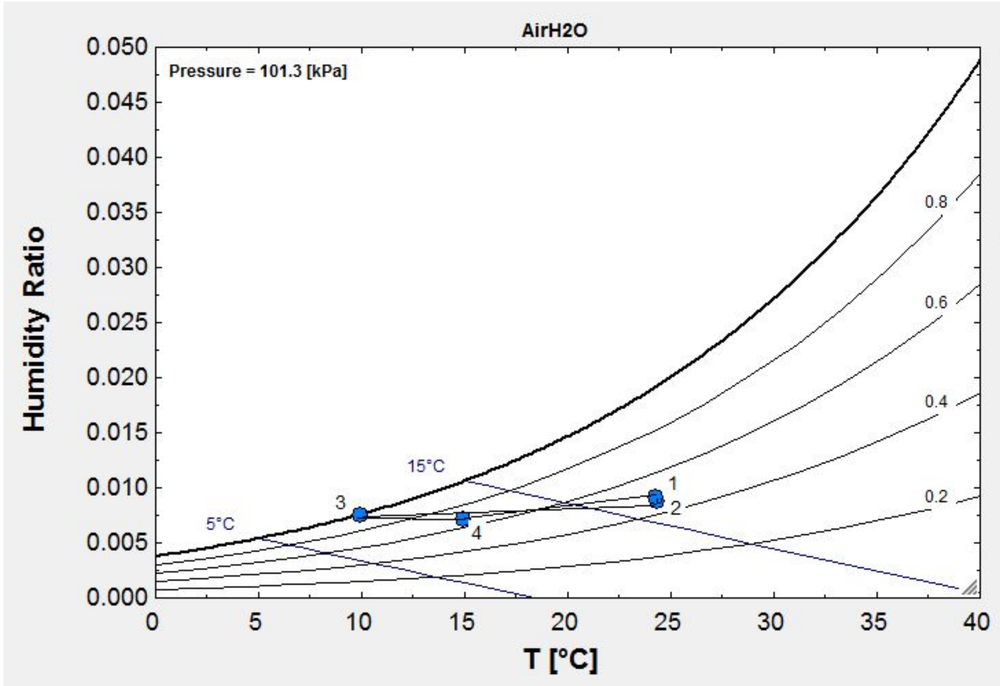

Figure 8: A screenshot of EES of the air side data at 6 o'clock plotted on a psychrometric chart.

Table 1: Table including the measured air velocity and heat transfer and calculated air velocity using the Bernoulli Equation and the calculated heat transfer at three different fan speeds.

	12 o'clock	**3 o'clock**	**6 o'clock**
Measured Air Velocity (m/s)	4.8 (±0.1)	9.1 (±0.2)	11.9 (±0.3)
Calculated Air Velocity	5.386	10.2	12.91
$Q_{evap, measured}$ (Btu/hr)	4737	7386	7452
$Q_{evap, calculated}$ (Btu/hr)	5315	8276	8066

Chapter 4: Testing R134a Refrigerant

The thermodynamic properties of the air and refrigerant are measured using the four hydrometers and the other temperature and pressure sensors. All the temperature sensors came calibrated with the system. The volumetric flow rate of the refrigerant is recorded using the flow meter with the units of L/hr and converted into m^3/s. The current of the compressor and fan is measured by using a current transformer (CT) clamp.

The tests have the the first heating element set to 35°C and the second heating element set to 5°C and The fan is set to 12 o'clock. The velocity is measured by placing the anemometer in the adjusted opening and was recorded. The system runs until all the temperature, pressure and electric current readings remain at steady state. The temperature readings are observed by using the switch knob on the control console. Next, the pressures are observed on the pressure gages and recorded as well. After that, the refrigerant flow rate is observed and by looking at the flow meter. Finally, the currents of the fan and condenser are measured using the CT clamp. All these measured values are recorded onto a spreadsheet. This process is repeated two more times by turning the fan speed to 3o'clock and finally 6 o'clock. The system was attached to a steamer however the results are omitted because mixing a moderate amount steam into the process did not change the results much.

Table 2: This table includes the temperature settings of the heaters, steady current of the fan and condenser, temperature readings of the air air side for R-134a.

		R-134a Run #1	R-134a Run #2	R-134a Run #3
AR2	**Temperature Setting (°C)**	35	35	35
AR3	**Temperature Setting (°C)**	5	5	5
Fan	**Dial Location (m/s)**	12 o'clock (4.8±0.1)	3 o'clock (9.1 ±0.2)	6 o’clock (11.9 ±0.3)
Compressor		On	On	On
Steamer		Off	Off	Off
Avg Condenser Amps		4.0	4.3	4.5
Avg Fan Amps		0.1	0.2	0.2
ST-1	**Air at Fan Inlet Dry Bulb Temp (°C)**	22	23	24
ST-2	**Air at Fan Inlet Wet Bulb Temp (°C)**	16	16	16
ST-3	**Air After Pre-heat or Heat Injection Dry Bulb Temp (°C)**	24	24	24
ST-4	**Air After Pre-heat or Heat Injection Wet Bulb Temp (°C)**	12	16	16
ST-5	**Air After Cooling/Dehumidification Dry Bulb Temp (°C)**	4	9	10
ST-6	**Air After Cooling/Dehumidification Wet Bulb Temp (°C)**	4	8	10
ST-7	**Air After Reheating Dry Bulb Temp (°C)**	13	16	15
ST-8	**Air After Reheating Wet Bulb Temp (°C)**	8	12	8

Table 3: This table contains the refrigerant side temperatures, pressures and mass flow rate of R-134a.

Sensor Number		R134a Run #1	R134a Run #2	R134a Run #3
ST-9	**Evaporator Out Temperature (°C)**	5	8	9
ST-10	**Compressor Out Temperature (°C)**	27	29	29
ST-11	**Expansion Valve Out Temperature (°C)**	5	8	10
	Mass Flow Rate (L/hr)	36	39	40
	Evaporator Out Pressure (bar)	2.05	2.4	2.6
	Condenser Out Pressure (bar)	7	7	7.1
	Expansion Valve Out Pressure (bar)	2.1	2.6	2.7

After the data is collected, Engineering Equation Solver (EES)™ files are created to find more thermodynamic properties of the refrigerant. With the pressure and temperature values of the refrigerant EES is used to find properties like enthalpy and entropy which are required for later calculations. With the additional properties it is possible to calculate the transfer of heat for refrigerant side, the coefficient of performance (COP), and the effectiveness of the heat transfer between the air and refrigerant.

The transfer of heat, in Btu/hr is found using Equation (3)

$$\dot{Q}_{evap} = \dot{m}(h_1 - h_4) \qquad (3)$$

Where Q is the amount of heat transferred in kW, $\dot{m}$ is the mass flow rate of refrigerant in kg/s, h_1 is the enthalpy of the refrigerant at the evaporator outlet and h_4 is the enthalpy of the refrigerant at the evaporator inlet. The work of the compressor is found using the equation

$$\dot{W}_{comp} = \dot{m}(h_2 - h_1) \qquad \textbf{(4)}$$

Where *W* is the amount of work done by the compressor in kW, *m* is the mass flow rate of refrigerant in kg/s, h_2 is the enthalpy of the refrigerant at the condenser outlet and h_1 is the enthalpy of the refrigerant at the condenser inlet. The COP is calculated using the solutions from equations (3) and (4).

$$COP = \frac{\dot{Q}_{evap}}{\dot{W}_{comp}} \qquad \textbf{(5)}$$

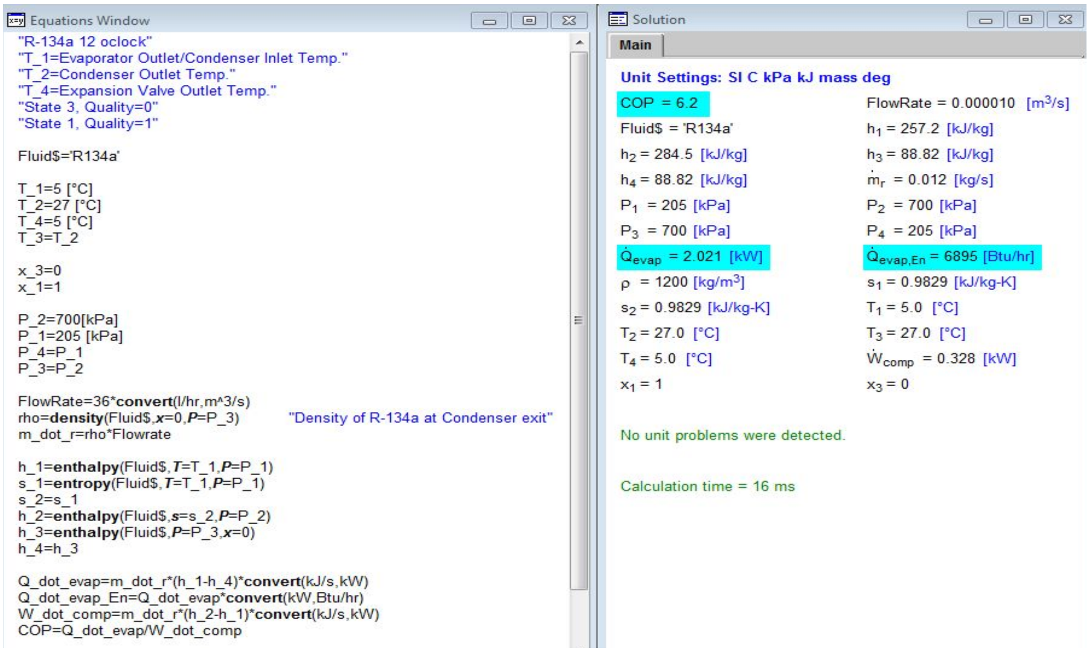

Figure 9: A screenshot of EES of the data collected using the R-134a refrigerant and the fan set at 12 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

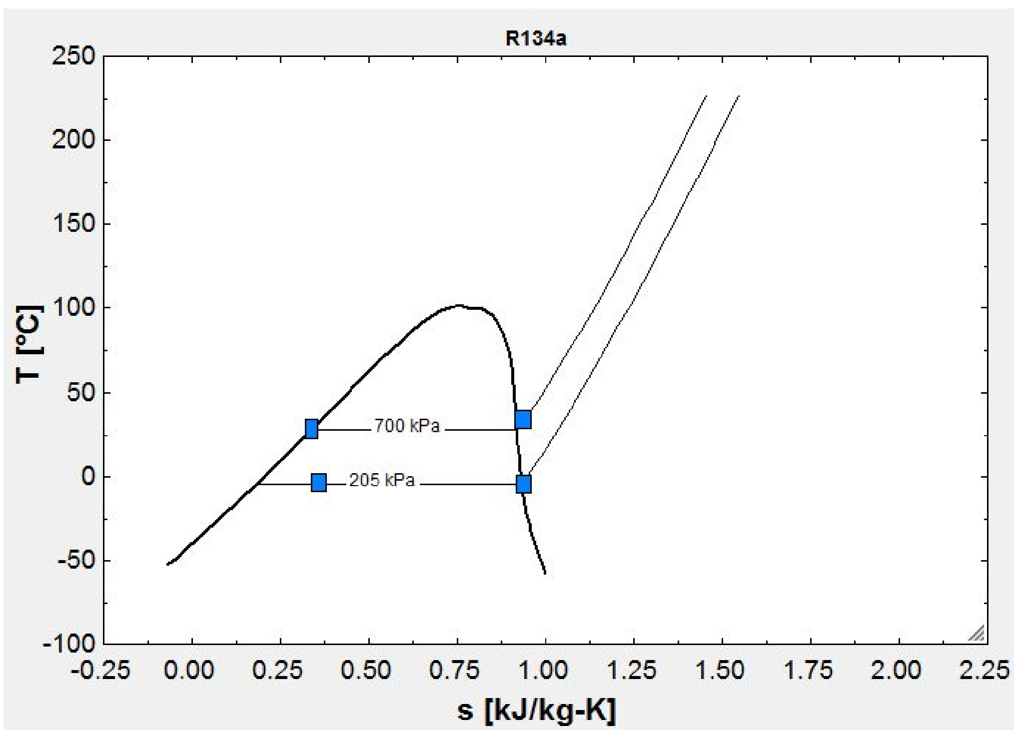

Figure 10: A T-s diagram of the temperature and calculated entropy of R134a with the fan set at 12 o'clock.

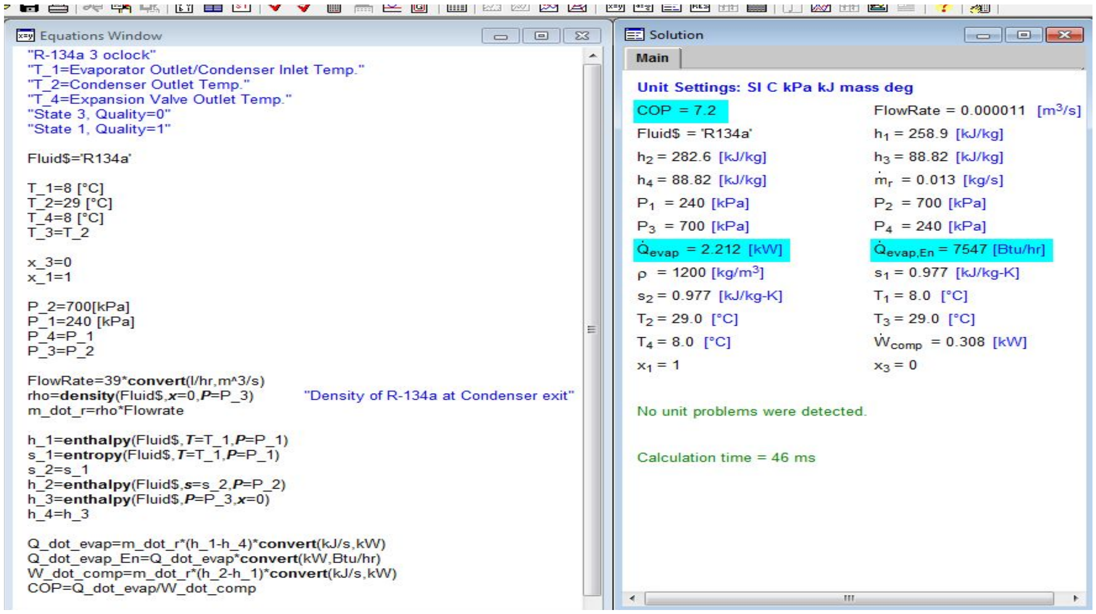

Figure 11: A screenshot of EES of the data collected using the R-134a refrigerant and the fan set at 3 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

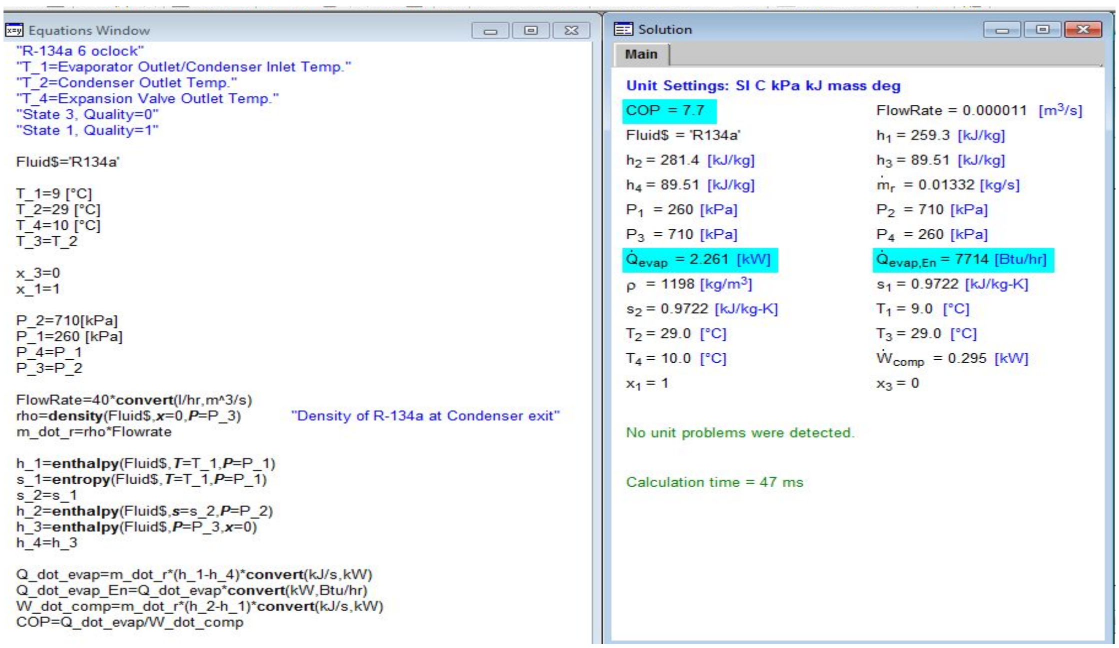

Figure 12: A screenshot of EES of the data collected using the R-134a refrigerant and the fan set at 6 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

Table 4: Table including the fan speed with calculated COP and heat transfer in kW and Btu/hr for R134a at three different fan speeds.

	R134a Test #1	**R134a Test #2**	**R134a Test #3**
Fan Speed (m/s)	4.8 (±0.1)	9.1 (±0.2)	11.9 (±0.3)
COP	6.2	7.2	7.7
Q_{evap} (kW)	2.021	2.212	2.261
Q_{evap} (Btu/hr)	6895	7547	7714

$$Heat\ Transfer\ Effectiveness\ (\%) = \frac{\dot{Q}_{refrigerant}}{\dot{Q}_{air}} \qquad \textbf{(6)}$$

The higher the percentage the less heat loss there is to the surrounding area or condensation when transferring heat.

Table 5: Table with the heat transfer effectiveness of R134a using the heat transfers of the air and R134a at three different fan speeds.

R134a	**12 o'clock**	**3 o'clock**	**6 o'clock**
Measured Air Velocity (m/s)	4.8 (±0.1)	9.1 (±0.2)	11.9 (±0.3)
$Q_{evap,\ R134a}$ (Btu/hr)	6895	7547	7714
$Q_{evap\ air,\ measured}$ (Btu/hr)	4737	7386	7452
Heat Transfer Effectiveness (%)	67.80	97.87	96.60

Chapter 5: Finding Theoretical Properties of R22 and R404A With TAAB System Running on R-134a

The thermodynamic properties of the air and refrigerant are measured using very similar techniques to find the properties of R134a. The four hydrometers will give the temperature of the air still while temperature and pressure sensors will give us the temperatures of the refrigerants. The volumetric flow rate of the refrigerant is recorded using the flow meter with the units of L/hr and converted into m^3/s. The velocity of the air is measured using an anemometer with the opening being the exact size of the anemometer and double checked by calculating it using the area and pressure of the measured air flow. The current of the compressor and fan is measured by using a CT clamp.

The first test has the the first heating element set to 35°C and the second heating element set to 5°C and the fan is set to the 12 o'clock position. The velocity is measured by placing the anemometer in the adjusted opening and recorded. The system runs until all the temperature, pressure and electric current readings are at steady state. The air temperatures are found by turning the number knob on the control console. However the pressure and temperature readings are found by reading the corresponding refrigerant on the temperature and pressure gage.

Figure 13: The gage that provides the pressure at which the system is working at along with the temperatures of R134a, R22 and R404A at that pressure

The same air data calculated for the fan speeds of 12, 3, and 6 o'clock are compared to the different refrigerant data collected through the refrigerant temperature and pressure sensors. Just like with the data collected for R-134a , Engineering Equation Solver (EES) files are created to find more thermodynamic properties of the refrigerants. With the pressure and temperature values of the refrigerants EES is used to to find properties like enthalpy and entropy which are required for later calculations. COP, total heat transfer, and effectiveness can be calculated using the new properties found. The heat transfer, work of the compressor, COP and heat transfer effectiveness (3), (4), (5) and (6) respectively.

Table 6: This table includes the refrigerant temperature of R22 at the working pressure of a system running on R134a.

Sensor Number		R22 Run #1	R22 Run #2	R22 Run #3
ST-9	**Evaporator Out Temperature (°C)**	-14	-10	-10
ST-10	**Compressor Out Temperature (°C)**	10.9	10.9	11.4
ST-11	**Expansion Valve Out Temperature (°C)**	-13	-9.5	-9
	Mass Flow Rate (L/hr)	36	39	40
	Evaporator Out Pressure (bar)	2.05	2.4	2.6
	Condenser Out Pressure (bar)	7	7	7.1
	Expansion Valve Out Pressure (bar)	2.1	2.6	2.7

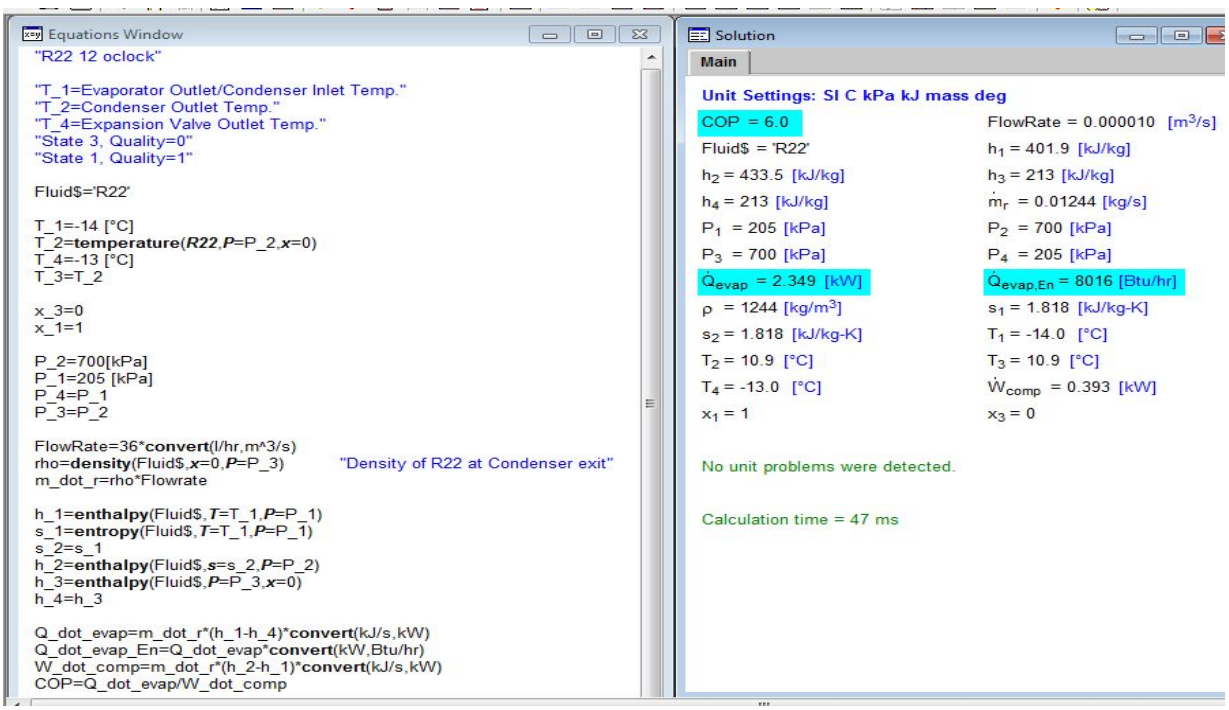

Figure 14: A screenshot of EES of the data collected using the R22 refrigerant and the fan set at 12 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

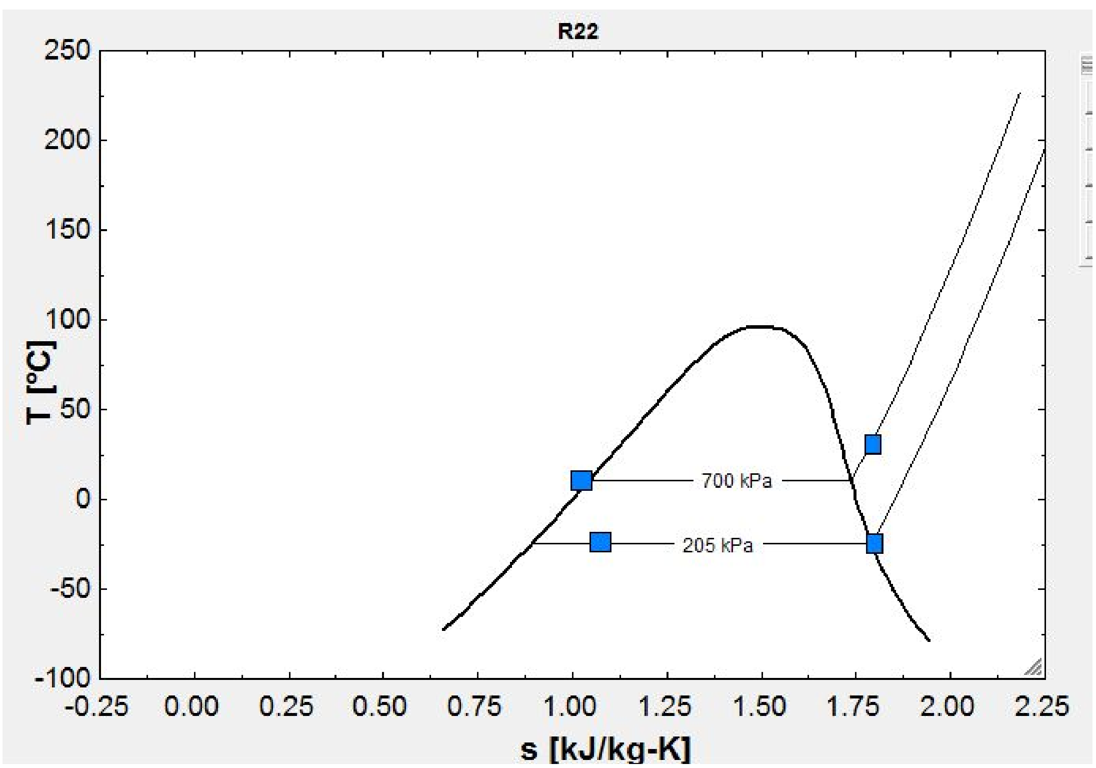

Figure 15: A T-s diagram of the temperature and calculated entropy of R134a with the fan set at 12 o'clock.

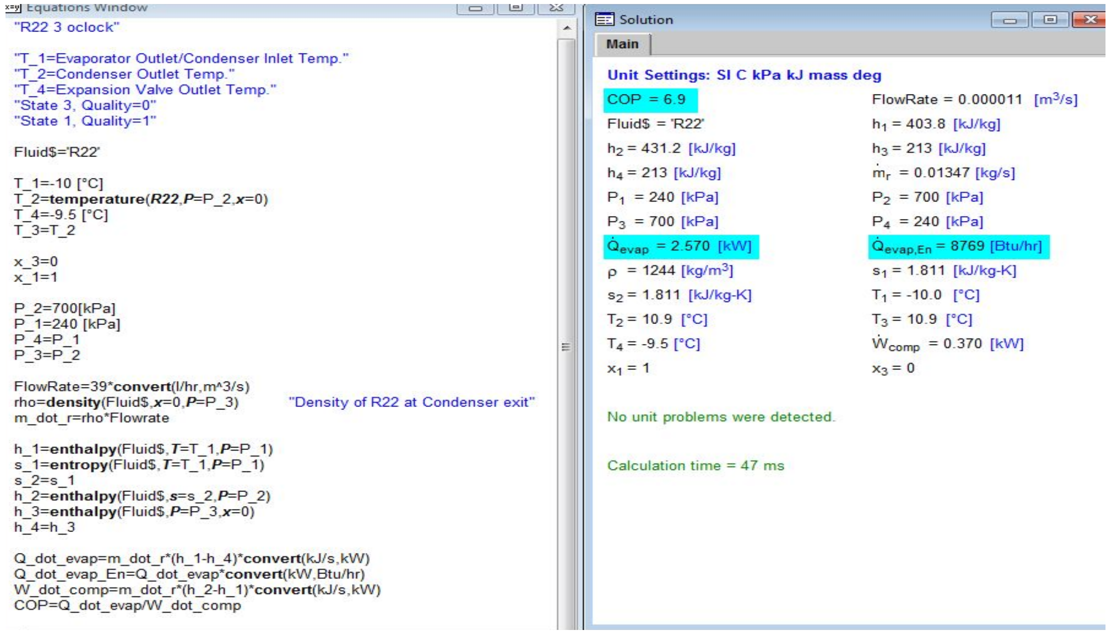

Figure 16: A screenshot of EES of the data collected using the R22 refrigerant and the fan set at 3 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

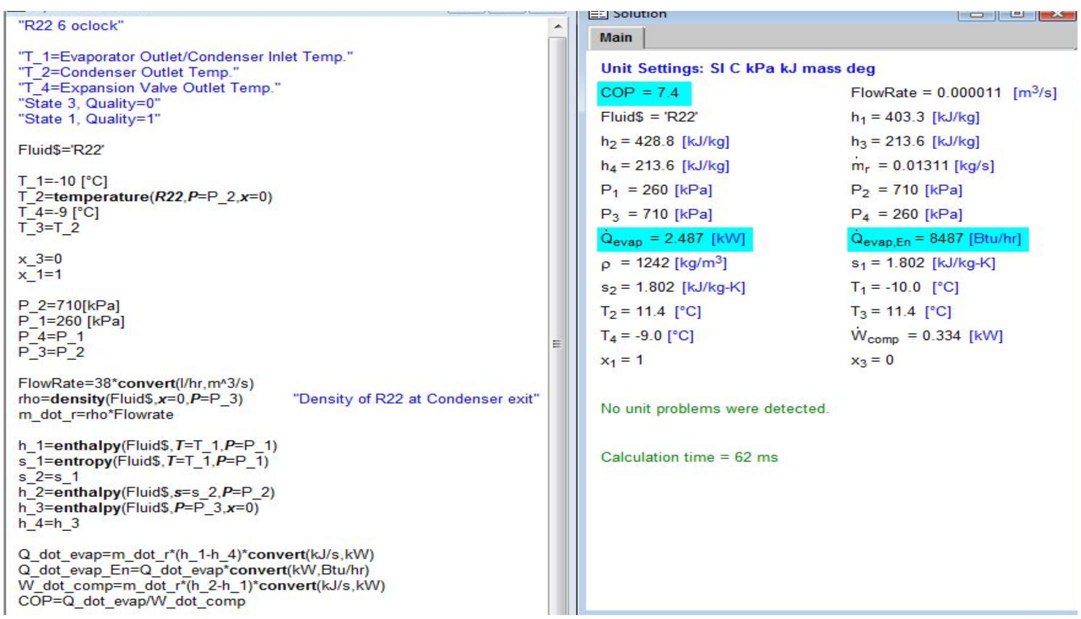

Figure 17: A screenshot of EES of the data collected using the R22 refrigerant and the fan set at 6 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

Table 7: Table including the fan speed with calculated COP and heat transfer in kW and Btu/hr for R22 at three different fan speeds.

	R22 Test #1	R22 Test #2	R22 Test #3
Fan Speed (m/s)	4.8 (+/-.1)	9.1 (+/-.2)	11.9 (+/-.3)
COP	6.0	6.9	7.4
Q_{evap} (kW)	2.349	2.570	2.487
Q_{evap} (Btu/hr)	8016	8769	8487

Table 8: Table with the heat transfer effectiveness of R22 using the heat transfers of the air and R22 at three different fan speeds.

R22	12 o'clock	3 o'clock	6 o'clock
Measured Fan Speed (m/s)	4.8 (+/-.1)	9.1 (+/-.2)	11.9 (+/-.3)
$Q_{evap,\ R22a}$ (Btu/hr)	8016	8769	8487
$Q_{evap\ air,\ measured}$ (Btu/hr)	4737	7386	7452
Heat Transfer Effectiveness (%)	59.09	84.23	87.80

T**able 9:** This table includes the refrigerant temperature of R404A at the working pressure of a system running on R134a.

Sensor Number		R404 Run #1	R404 Run #2	R404 Run #3
ST-9	**Evaporator Out Temperature (°C)**	-20	-17	-16
ST-10	**Compressor Out Temperature (°C)**	4.4	4.4	4.9
ST-11	**Expansion Valve Out Temperature (°C)**	-19	-16	-15
	Mass Flow Rate (L/hr)	36	39	38
	Evaporator Out Pressure (bar)	2.05	2.4	2.6
	Condenser Out Pressure (bar)	7	7	7.1
	Expansion Valve Out Pressure (bar)	2.1	2.6	2.7

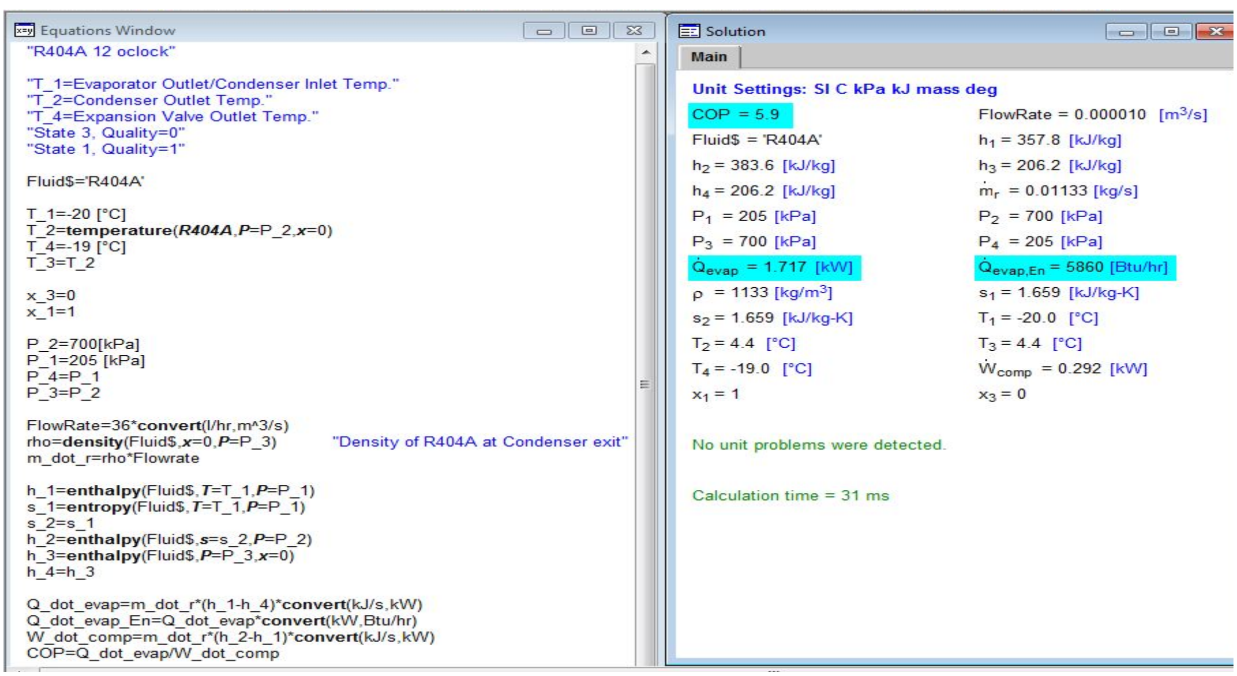

Figure 18: A screenshot of EES of the data collected using the R404A refrigerant and the fan set at 12 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

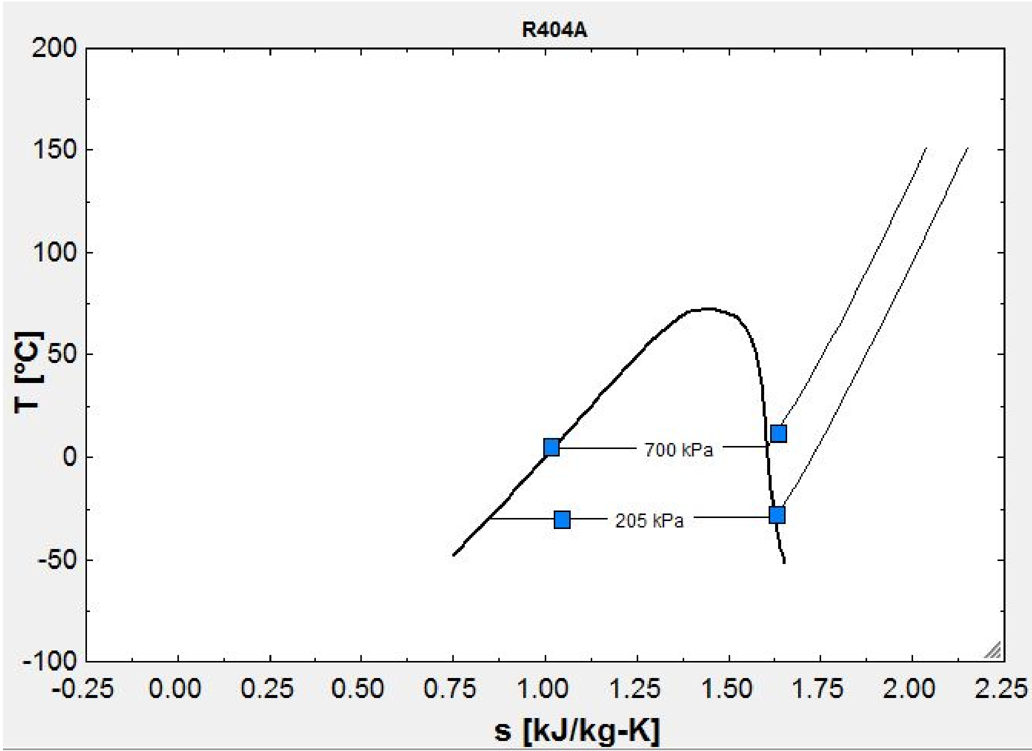

Figure 19: A T-s diagram of the temperature and calculated entropy of R134a with the fan set at 12 o'clock.

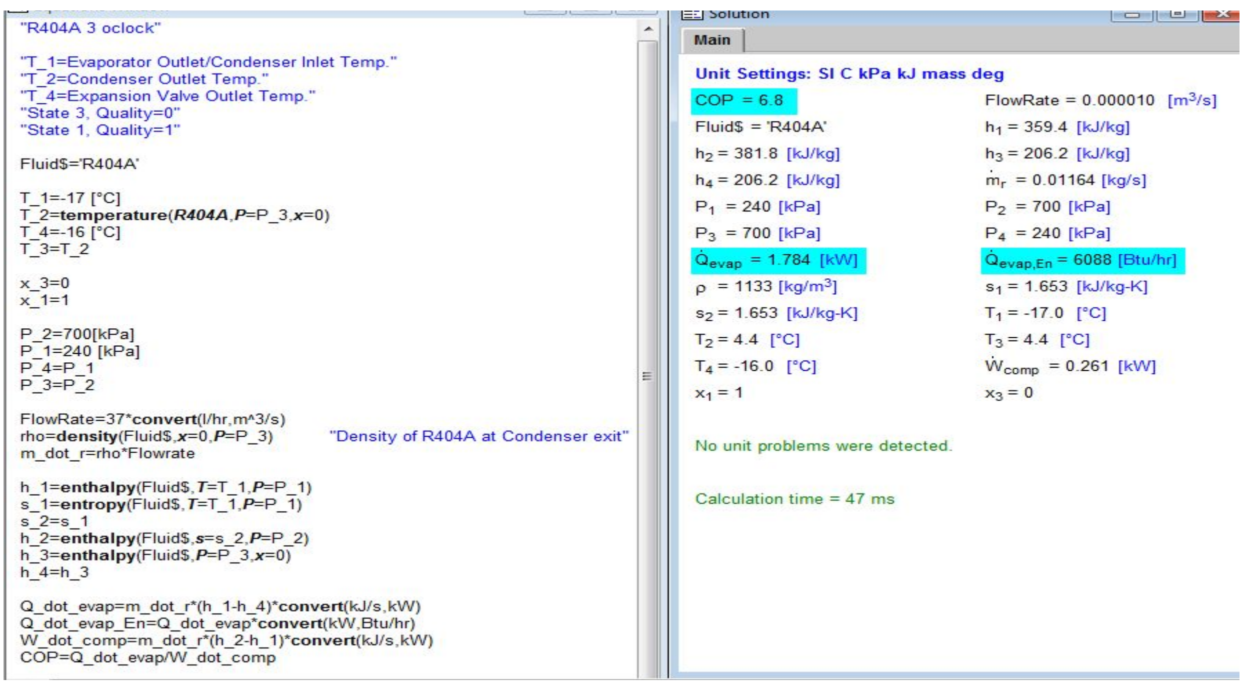

Figure 20: A screenshot of EES of the data collected using the R404A refrigerant and the fan set at 3 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

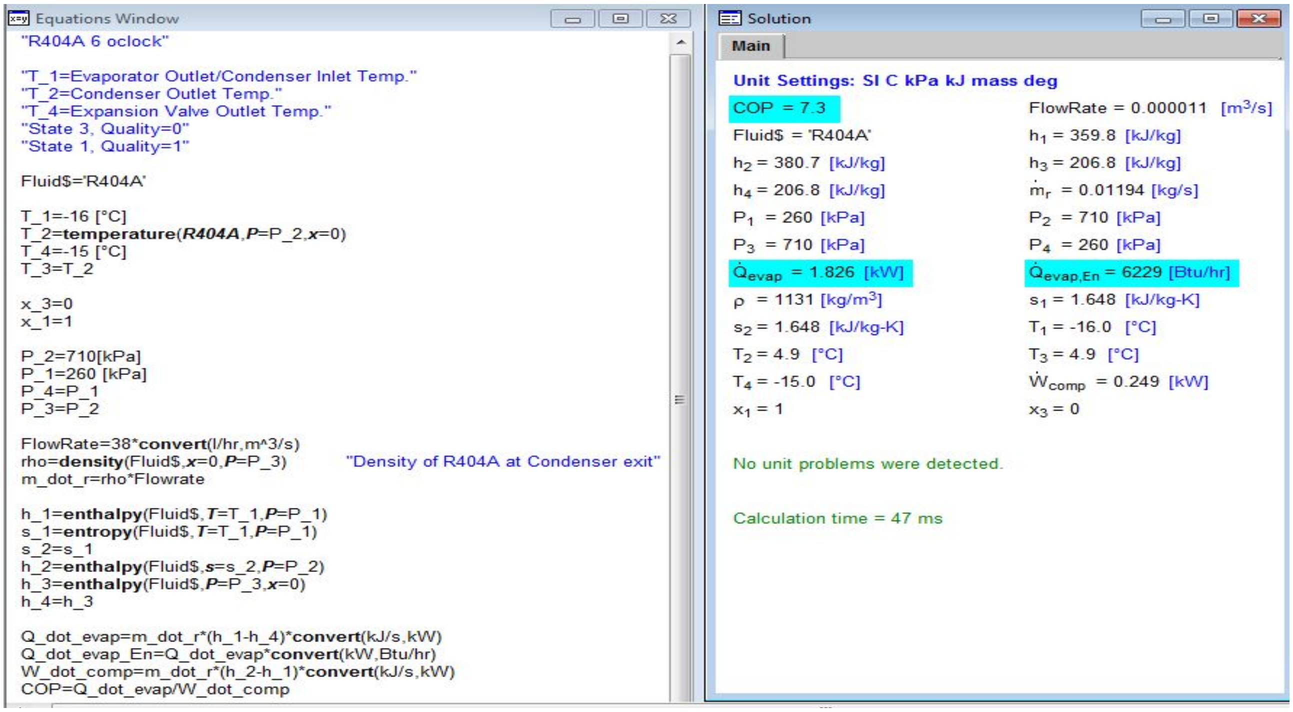

Figure 21: A screenshot of EES of the data collected using the R404A refrigerant and the fan set at 6 o'clock. Thermodynamic properties, heat transfer, work and COP are calculated.

Table 10: Table including the fan speed with calculated COP and heat transfer in kW and Btu/hr for R404A at three different fan speeds.

	R404A Test #1	**R404A Test #2**	**R404A Test #3**
Fan Speed (m/s)	4.8 (+/-.1)	9.1 (+/-.2)	11.9 (+/-.3)
COP	5.9	6.8	7.3
Q_{evap} (kW)	1.717	1.784	1.826
Q_{evap} (Btu/hr)	5860	6088	6229

Table 11: Table with the heat transfer effectiveness of R134a using the heat transfers of the air and R134a at three different fan speeds.

R404A	**12 o'clock**	**3 o'clock**	**6 o'clock**
Measured Fan Speed (m/s)	4.8 (+/-.1)	9.1 (+/-.2)	11.9 (+/-.3)
$Q_{evap,\ R404A}$ (Btu/hr)	5860	6088	6229
$Q_{evap\ air,\ measured}$ (Btu/hr)	4737	7386	7452
Heat Transfer Effectiveness (%)	80.84	121.32	119.63

Chapter 6: Refrigerant Results and Comparison

Table 12: Contains calculated data for the COP, heat transfer of the refrigerant, heat transfer of the air and the heat transfer effectiveness of R134a, R22 and R404A.

	R134a	R22	R404A
COP (12 o'clock)	6.2	6.0	5.9
COP (3 o'clock)	7.2	6.9	6.8
COP (6 o'clock)	7.7	7.4	7.3
Qevap Refrigerant (Btu/hr) (12 o'clock)	6895	8016	5860
Qevap Refrigerant (Btu/hr) (3 o'clock)	7547	8769	6088
Qevap Refrigerant (Btu/hr) (6 o'clock)	7714	8487	6229
Qair (Btu/hr) (12 o'clock)	5315	5315	5315
Qair(Btu/hr) (3 o'clock)	7386	7386	7386
Qair (Btu/hr) (6 o'clock)	7452	7452	7452
Heat Transfer Effectiveness (%) (12 o'clock)	77.08	66.30	90.70
Heat Transfer Effectiveness (%) (3 o'clock)	97.87	84.23	121.32
Heat Transfer Effectiveness (%) (6 o'clock)	96.60	87.80	119.63

R134a has the highest COP at every fan speed. At the 12 o'clock position is was 0.2 higher than R22 and 0.3 higher than R404A. At the 3 o’clock position it was 0.3 higher than R22 and .4 higher than R404A. Finally, at 6 o’clock fan position it was 0.3 higher than R22 and 0.4 higher than R404A. R22 has the second best COP at all the fan speeds and R404A has the worst COP at all the fan speeds. This TAAB system is built to run off of R134a which helps explain why it has the best COP at all speeds. If the other refrigerants were working at pressures more optimal to them, they’re COP would end up being better.

There are much bigger differences between the heat transfer of the different refrigerants. R134a has the second highest heat transfer of all the three refrigerants. R22 has the highest amount of heat transfer of the three and R404A has the lowest. For R134a and R404A as the fan speed increases, so did the heat transfer rate. This could be due to the mass flow rate of the refrigerant increasing as well. However R22 does not follow this trend. R22's heat transfer rate increased when the fan is turned from 12 o'clock to 3 o'clock but decreases when turned from 3 o'clock to 6 o 'clock. R22 has a heat transfer rate at least 773 Btu/hr higher than the other refrigerants tested.

The heat transfer effectiveness for R134a and R404A follow a similar pattern. The effectiveness increases when the fan speed is increased from 12 o'clock to 3 o'clock but again the effectiveness decreases fan speed is increased from 3 o'clock to 6 o'clock. This could be due to the fact that the system is not meant to run on its maximum capacity for long amounts of time. R134a starts off with a lower effectiveness but quickly increases when the air velocity is increased as well. R404A exceeds 100% effectiveness. This could be due to R404A not being physically tested and not knowing what pressures the refrigerant would be under in the TAAB Lab Air Conditioning Unit. If R404A is omitted because its effectiveness exceeds 100% R134a would have the highest effectiveness. The system was built to run on R134a which helps explain why it is higher than the other refrigerant, R22.

Chapter 7: Conclusions

In this report, an experimental analysis of an Edibon TAAB: Air Conditioning Lab Unit at various fan speeds and with real and theoretical refrigerants was presented. Tests were completed at three different fan speeds, one refrigerant was physically used and two were simulated using EES software. The main conclusions can be summarized as the following

- R134a had a higher COP by at least 0.2 at every fan speed compared to R22 and R404A.
- R22's heat transfer is at a minimum 773 Btu/hr higher when compared to R134a and R404A at the three fan speeds tested.
- As the speed of the fan increases, the air velocity increases and the heat transfer rate of the air increases.
- Percentage wise R404A has the best heat transfer effectiveness but since it was not physically tested and exceeded 100% effectiveness R134a is considered the most effective when it comes to heat transfer in this unit.

Chapter 8: Future Work

In this paper the COP, heat transfer of air and R134a and heat transfer effectiveness was physically tested. These conclusions were also reached for R22 and R404A but only theoretically. The next step to take is actually replacing the R134a with R22 or R404A and testing how either of those refrigerants run in the TAAB air conditioning unit. Completing the same tests with the new refrigerants can give a more accurate comparison of the COP and heat transfers between the refrigerants. Other refrigerants besides R134a, R22, R404A could be tested to get a wider array of comparison results allowing to reach a deeper understanding of the refrigeration process

To help accurately repeat the testing process of my experiment an ISAT 301 type lab manual can be created. The new lab could be much more consumer friendly than the one sent with the unit helping for easier recreation of the experiment. The lab would involve step by step directions to make sure all the settings are as close to the original for the most accurate comparison results. The lab manual could also include more than just directions to recreate my experiment. Different testing conditions, like heating instead of cooling, can also be included to see how the heat transfer changes at various conditions.

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